

4.4 GEOLOGY AND SOILS

This section describes the marine geologic issues along the proposed MARS cable route, extending 51 km offshore, from Moss Landing to the southeastern part of the Smooth Ridge, located on the continental shelf of Monterey Bay. The cable route and general vicinity is considered the study area for the geology and soils analysis. A general description of the regional geology is followed by a detailed description of the marine geology and geology of the landing areas. Section 4.4 also identifies the applicable significance criteria for evaluating impacts on geology and soils, and assesses potential impacts of the Project related to geology and soils.

4.4.1 Environmental Setting

Regional Geology

Regional Tectonics and Stratigraphy

The present day geology of the Central California region is the result of evolving tectonic processes over the past 65 million years (Greene 1990). The dominant tectonic process from the Cretaceous through the middle Tertiary was subduction along two converging plates: the Farallon Plate subducting eastward under the overriding North American Plate. In the early Miocene (21 million years ago), the regional tectonics evolved to the present day condition. The convergent plate margin switched to a transform plate margin when subduction of the Farallon Plate ceased and was replaced by northwest movement along the western Pacific Plate and the eastern North American Plate (Dickenson 1981).

The Monterey Bay region overlies a large mass of Cretaceous granitic rocks termed the Salinian Block. Overlying the granitic basement rock is a thick sequence of Tertiary strata, including the Miocene Monterey Formation, Santa Cruz Mudstone, and the Pliocene Purisima Formation. Within Monterey Bay, the Miocene Monterey Formation (a thin- to medium-bedded, marine mudstone and sandy siltstone) unconformably overlies the granitic basement. The Monterey Formation, in turn, is unconformably overlain by the Pliocene Purisima Formation, which is comprised of moderate- to well-consolidated sandstone, siltstone, and mudstone. Further offshore, the Purisima Formation directly overlies the Salinian Block. Close to shore and in the seaside cliffs north of Santa Cruz, the Purisima Formation unconformably overlies the late Miocene Santa Cruz Mudstone, a highly fractured, folded, and faulted mudstone that is exposed in the cliffs just north of Santa Cruz (Best and Griggs 1991; Clark 1981; Greene 1977, 1990; Greene and Clark 1979; Greene et al. 2002; McCulloch and Greene 1990; Wagner et al. 2002).

1 Since the early Miocene, the Salinian Block has been carried northward on the Pacific
2 Plate along the active transform plate boundary between the Pacific and North
3 American tectonic plates. The relative motion between the two plates is described as
4 right-lateral strike-slip. This motion is accommodated by the seismically active, ~100
5 km wide San Andreas Fault System (Greene 1977; Greene and Clarke 1979; Howell et
6 al. 1980).

7 The San Andreas Fault System consists of many active or potentially active fault
8 systems, including the onshore/offshore San Andreas Fault, the onshore/offshore Palo
9 Colorado-San Gregorio Fault Zone, and the Monterey Bay Fault Zone (Greene 1977,
10 1990; Silver 1978; Wagner et al. 2002). The faults most pertinent to the Project are
11 shown in Figure 4.4-1. Transpressional forces caused by right-lateral strike-slip motion
12 along the San Andreas Fault System commonly produce earthquakes, submarine
13 landslides, turbidity currents, and coastal erosion (Atwater 1970; Howell et al. 1980;
14 Howell et al. 1985; Page and Engebretson 1984; Greene and Hicks 1990; Greene et al.
15 2002).

16 The offshore Monterey Bay Fault Zone is an approximate 6 mile (10 km) wide series of
17 generally parallel, northwest-southeast trending fault strands, ranging from less than 3
18 to over 9 miles (5 to 15 km) long. The fault zone bisects the Monterey Bay continental
19 shelf and may merge with the San Gregorio fault in northern Monterey Bay. The Project
20 cable route crosses the Monterey Bay Fault Zone along the northern Monterey Bay
21 continental shelf. Quaternary sediments covering the shelf show no evidence of
22 disturbance or surface rupture caused by faulting in this region (Greene 1977; Fugro
23 2004). Data collected as part of the Monterey Bay Ocean Bottom International Seismic
24 Experiment (MOISE) greatly improved the ability to characterize the sub-seafloor
25 geology of the Monterey Bay Region, demonstrating that small to moderate quakes on
26 the Monterey Bay Fault Zone are nearly pure strike-slip, meaning the faults express little
27 thrust displacement (Begnaud and Stakes 2000; Begnaud et al. 2000; Greene 1990;
28 Greene et al. 2002).

29 The Palo-Colorado-San Gregorio Fault Zone is approximately 1 to 2 miles (2 to 3 km)
30 wide and comprised of several generally parallel, right-lateral strike-slip fault strands,
31 which extend approximately 125 miles (200 km), from Garrapatta Beach in the south to
32 Año Nuevo Point north of Monterey Bay (Figure 4.4-1) (Greene 1977, 1990; Greene et
33 al. 2002; Clark et al. 1999; Eittreim et al. 2002b). The largest fault within this system is
34 the San Gregorio Fault. The results of MOISE for the San Gregorio Fault concluded
35 that earthquakes along this fault produce primarily oblique convergence and thrust
36 motions (Begnaud and Stakes 2000; Begnaud et al. 2000; Stevenson et al. 1996). The
37 Project cable route crosses the San Gregorio Fault near the upper continental slope.

1 Placeholder for Figure 4.4-1 Location of Important Fault Zones

Evidence collected in independent studies conducted by a variety of scientists has indicated that from 50 to 95 miles (~80 to 150 km) of offset has occurred along the Palo Colorado-San Gregorio Fault Zone over time and that offsets (horizontal and thrust) will probably continue in the future (Clark et al. 1984; Graham and Dickenson 1978; Greene 1977; Weber 1990). As a result of this offset, the stratigraphy on the eastern side of the fault is different than on the western side. Strata on the eastern side of the fault zone consists of that previously described, i.e., Salinian granite, Purisima Formation, etc. On the western side of the fault zone lies the Franciscan complex, a metamorphosed, fragmented mixture of oceanic crust (basalt), overlying strata, and residual sediment from the previous geologic subduction regime (Mason 1990; Peacock 1992). A zone of deformation exists where the fault is interpreted to emerge on the seafloor near the shelf break. The zone is a fractured mixture of numerous rock and sediment types that are impossible to differentiate without the analysis of physical samples.

Another fault zone in the vicinity of the Project is the Ascension Fault Zone (Figure 4.4-1), which lies approximately 3 miles (5 km) west of the Palo Colorado-San Gregorio Fault Zone and is nearly parallel to it for almost 44 miles (70 km), from Point Sur to the southernmost head of Ascension Submarine Canyon. This fault zone is not as well defined as others in the region and appears to have both strike-slip and thrust movement (Nagel et al. 1986; Greene 1997, 1990).

Submarine Canyon Systems in Monterey Bay

The Monterey Canyon System is composed of Monterey, Soquel, and Carmel Canyons (Figure 4.4-2). Soquel Canyon is a relatively linear, approximate 6 mile (9 km) long canyon that traverses southwest across the northern Monterey Bay shelf and intersects Monterey Canyon at a depth of 3,280 feet (~1000 m), over 11 miles (~18 km) offshore from Monterey Canyon head near Moss Landing. Carmel Canyon is also relatively linear and joins Monterey Canyon from the south as a stepped chute, at a depth of 6,560 feet (~2000 m) (Greene and Hicks 1990; Greene 1990; Greene et al. 2002; Mitts 2003).

Monterey Canyon is a complex, sinuous submarine canyon that bisects the crescent-shaped Monterey Bay. It is one of the largest geologically active submarine canyons on the west coast of North America and is the result of tectonic activity and erosion through layers of Neogene strata and into the Cretaceous granitic basement complex known as the Salinian Block. The Canyon has at least 11 branches which cut into the seaward edge of the continental slope. The Canyon itself has many unique curves and meanders, the three most prominent being Gooseneck, Monterey, and San Gregorio

1 Placeholder for Figure 4.4-2 Monterey Submarine Canyon System

meanders (Figure 4.4-1). The positions and geomorphology of the meanders are believed to be the result of movement along two different fault zones and may continue to evolve as a result of continuing tectonic activity (Greene and Hicks 1990; Greene et al. 1991b; Greene et al. 1989; Greene et al. 2002).

The Canyon originates in four submarine canyon heads, ranging from 100 to 330 feet (30 to 100 m) offshore Moss Landing Harbor (Greene 1990) (Figure 4.4-2). Sand eroded from beaches and mixed sediment delivered to the coast by rivers is transported in littoral drift from both the northern and the southern parts of Monterey Bay towards the canyon heads. As much as 523,000 yd³ (400,000 m³) of sand per year is actively transported down canyon, as well as additional sediment derived from slumping and erosion of canyon walls. Multibeam bathymetry images reveal a sediment transport pattern on the seafloor that is similar to those observed in fluvial processes (Best & Griggs 1991; Greene et al. 2002; Wolf 1970; Mitts 2003).

A fault inferred (believed to be inactive) in the head of Monterey Canyon is termed the Monterey Canyon Fault (Wagner et al. 2002). This fault runs roughly perpendicular to the canyon axis and is truncated further offshore by a fault strand of the Monterey Bay Fault Zone.

The upper canyon is an active erosional feature with steep walls and a narrow canyon floor, exhibiting a V-shaped cross-sectional profile. Landslides and turbidity currents created by mass wasting events erode the canyon wall and have exposed granitic rocks (Salinian Block). The erosion-resistant granitic rocks may have altered the course of sediment transport down the canyon and possibly controlled creation of Gooseneck Meander, at a depth of approximately 1,900 feet (~585 m) (see Figure 4.4-1) (Greene 1990; Greene et al. 2002).

Further down canyon a broad s-curve has formed between the depths of roughly 2,800 through 5,750 feet (~850 through 1750 m). The curve is composed of two fault controlled meanders, including Monterey and San Gregorio meanders. Monterey Meander is believed to be structurally controlled by the Monterey Bay Fault Zone and the San Gregorio Meander by the Palo Colorado-San Gregorio Fault Zone (see Figure 4.4-1). The Canyon walls are steep in this area, but the Canyon floor has become wider and begins to transition from a V-shaped to U-shaped cross-sectional profile (Greene 1990; Greene et al. 2002).

Seaward of the San Gregorio Meander, the Monterey Canyon trends southwestward and constitutes the southeastern border of a large, broad, bathymetric high termed Smooth Ridge. In this portion of the Canyon, extensive mass wasting has occurred and

1 numerous, fresh slump scars have been mapped by Greene et al. (2002). The Canyon
2 floor continues to widen and flatten downslope, eventually broadening to a width of over
3 2 miles (3.5 km) and exhibiting a braided sedimentary morphology similar to terrestrial
4 river systems. Finally at the base of the continental slope, nearly 56 miles (90 km)
5 across the continental margin, the Canyon opens into Monterey Fan Valley, a deep-sea
6 turbidite fan deposit, reaching a final depth of nearly 2.5 miles (12,795 feet or ~3,900 m)
7 at the base of the continental rise (Greene 1990; Greene et al. 2002).

8 The Ascension Submarine Canyon System lies northwest of Monterey Canyon and the
9 Project cable route. The canyon system is formed from 11 canyon heads with three
10 primary tributary canyons: the Ascension, Año Nuevo, and Cabrillo canyons (Figure
11 4.4-2). Aside from slumping which occurs on the northwestern wall of Año Nuevo
12 Canyon, these canyons are not presently active and have not been active since the low
13 sea level stand during the Pleistocene, 12,000 years ago. However, mass wasting
14 events may occur in these canyons due to strong local earthquakes. The Cabrillo
15 Canyon flanks the northwestern edge of Smooth Ridge, which is discussed below
16 (Nagel et al. 1986, Greene 1990; Greene et al. 2002).

17 *Coastal Zone Geology*

18 A complex interaction between approaching waves, diverse coastline orientations, a
19 harbor channel, and abrupt canyon bathymetry, creates a variety of different sediment
20 transport and depositional possibilities at Moss Landing. In general, sediment is
21 transported towards Moss Landing from both the north and south in wave-driven littoral
22 drift and trapped in the heads of Monterey Canyon. Figure 4.4-3 indicates the flow of
23 sediment transport into the Monterey Submarine Canyon in relation to the proposed
24 Project route and Alternative landing sites. As much as 523,000 yd³ (400,000 m³) of
25 sand/year is actively transported down canyon, as well as additional sediment derived
26 from slumping and erosion of canyon walls (Best and Griggs 1991; Greene et al. 2002;
27 Wolf 1970; Mitts 2003). Sediment is derived from many sources, the most important
28 being the Pajaro River, approximately 1.5 miles north, and the Salinas River,
29 approximately 4 miles to the south (Best and Griggs 1991; Eittreim et al. 2002b). Other
30 sources include sand eroded from coastal beaches and dunes during intense storms
31 and high surf. This coast is particularly exposed to waves approaching from the
32 northwest, although west and southwest swells are also capable of transporting
33 sediment here (Xu 1999).

34 *Continental Shelf Geology*

35 Sedimentary processes of transportation, erosion, and deposition occur continually on
36 the continental margin of the Monterey Bay region. In addition, changes in sea level
37

1 **Placeholder for Figure 4.4-3 Sediment Transport Pathways into Monterey Canyon**

over time caused by alternating ice ages have influenced sediment distribution and produced an eroded and beveled surface on continental shelf bedrock. For example, approximately 18,000 years ago sea level was several miles seaward and approximately 400 feet (125 m) shallower than present day sea level, placing sea level at that time near the current position of the continental shelf break (Best and Griggs 1991; Edwards 2002; Eittreim et al. 2002a; Greene 1977, 1990; Griggs and Hein 1980; Lewis et al. 2002).

Shallow seismic reflection data indicate that nearshore sediments, to the depth of the proposed horizontal directionally drilled (HDD) borehole, consist of weakly consolidated sands and unconsolidated sands and gravels (personal communication, Charlie Paull 2005). Modern unconsolidated Quaternary sediments, consisting of fine sand, silt, and clay, are present on the northern Monterey Bay continental shelf, between depths of 100 to 295 feet (30 to 90 m) (Greene 1977; Best and Griggs 1991; Lewis et al. 2002; Eittreim et al. 2002b; Edwards 2002). Northern Monterey Bay current meter (Xu et al. 2002) and seismic reflection profile data (Greene 1977) suggest that sand, silt, and clay material is transported at these depths to the northwest by the poleward flowing Davidson Current (a fall/winter seasonal component of the California Current System), along a midshelf mudbelt, which extends from the continental shelf west of Moss Landing past Half Moon Bay (Figure 4.4-4). The mudbelt is up to 100 feet (30 m) thick and accumulates sediment at an average rate of 0.27 g/cm^2 per year (Lewis et al. 2002). The mudbelt overlies the Monterey Bay Fault Zone along the northern Monterey Bay continental shelf.

Continental Shelf Break and Smooth Ridge Slope Geology

According to Fugro (2004), the 295 feet (90 m) depth contour constitutes the shelf break and a change in seafloor substrate conditions from Quaternary mud sediments to outcroppings of the Pliocene Purisima Formation sandstone and siltstone. The outcrops are locally covered by a thin veneer of sediment of varying thickness, generally less than 2 feet (0.7 m) thick. In addition, Greene (1977), Wagner et al. (2002), and Wong and Eittreim (2002) have mapped patches of coarse sand, pebbles, and gravel in this area which may be relict beach deposits remaining from times of lower sea level.

Continuing down the continental slope towards the neck of Smooth Ridge, the terrain becomes increasingly steep and rugged with depth. The neck of Smooth Ridge is narrow (1.8 miles or ~3 km) and separates the Ascension Canyon System from the Monterey Canyon System. Numerous rock outcrops, scarps, and rubble have been mapped in this area, with little to no sediment cover. The neck broadens with depth, forming the irregularly shaped, relatively smooth topographic high called Smooth Ridge

(Figure 4.4-5). The irregular ridge slopes from about 985 feet (300 m) deep at the head to over 6,560 feet (2,000 m) at the base. The northern and southern flanks of Smooth Ridge exhibit numerous slump or slide scars that extend from the floor of Monterey Canyon well up the Smooth Ridge slope (Greene et al. 2002).

The San Gregorio Fault corresponds with the northeast flank of Smooth Ridge. Compressional forces along the fault may be causing the uplift of Smooth Ridge over time, increasing erosion along the southeastern and southern boundaries. Formation of a north-northwest/south-southeast trending trough that extends from the Monterey Canyon System is probably associated with this fault. A highly disturbed zone of deformation, likely caused by the fault, is present on the ridge at depths between 690 to 1020 feet (210 to 311 m). Numerous gullies and scarps extend up the northeastern flank of Smooth Ridge in this region (Orange et al. 1999; Greene et al. 1999; Greene et al. 2002). Further down the slope of Smooth Ridge, between depths of 1,475 through 2,925 feet (450 through 891 m), the seafloor slope becomes more gradual and sediment cover increases to over 6 feet (2 m).

Active chemosynthetic communities and methane-derived carbonate deposits are present on Smooth Ridge. These phenomena may be linked to several inactive and potentially active cold seeps which appear to be related to different dynamic geological processes based on the geochemistry of the fluids (Barry et al. 1996). Fluids may have reached these cold seeps by traveling several kilometers through underlying rocks and sediments along zones of structural weakness. Fluidized minerals may cause cementation of sediments, producing hard carbonate slabs and concretions similar to pavement. Carbonate mounds and rubble are produced by uniquely adapted chemosynthetic communities which biologically utilize the fluidized minerals and leave carbonate as a by-product. Clam Flat and Horseshoe Scarp South are the names given to two of the more thoroughly documented active communities, and Chimney Field and Horseshoe Scarp North are locations of hard carbonate deposits which may be past active communities (Figure 4.4-5) (Greene and Hicks 1990; Greene et al. 1999; Orange et al. 1999; Barry et al. 1996; McHugh et al. 1997).

Geohazards

Monterey Bay is subject to a variety of geohazards ranging from coastal erosion caused by intense winter storms, coastal flooding during El Niño events, and large magnitude earthquakes. Monterey Bay is seismically active, which has the potential to damage submarine and coastal facilities not only from the immediate surface rupture or ground shaking that an earthquake may cause, but more importantly from the effects that

- 1 **Placeholder for Figure 4.4-4 Sediment Depth along Continental Shelf**
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1 page 2 for Figure 4.4-4

- 1 Placeholder for Figure 4.4-5 Locations of Chemosynthetic Communities and Fluid
- 2 Seeps on Smooth Ridge

1 earthquakes may have on surrounding sediment stability or geologic structure.
2 Earthquakes provide the energy necessary to cause submarine slopes to fail, producing
3 turbidity currents, landslides, slumps, mass wasting events, and liquefaction.

4 *Coastal Geohazards*

5 Development anywhere along the California coastline involves a certain amount of risk.
6 The California coast is actively eroding due to violent storms, large waves, flooding,
7 earthquakes, and other hazards caused by earthquakes, such as liquefaction and
8 tsunamis. Harbors are also subject to erosion resulting from tidal scour, wind waves,
9 reflected waves, and boat wakes. These risks are multiplied by the fact that harbors,
10 being at sea level, are often reclaimed estuaries, which are on poorly consolidated
11 sediment, increasing the risk of flooding, tidal scour, and wave erosion.

12 Since the Moss Landing Harbor entrance channel was developed, tidal currents in and
13 out of the Elkhorn Slough have increased dramatically, causing extensive erosion in the
14 Harbor channel, adjacent banks, and throughout Elkhorn Slough to the east. According
15 to published reports by Haro, Kasunich and Associates, Inc. (1988), tidal current
16 velocities of 3.6 feet per second (capable of transporting sand and silt sediment) have
17 been measured at the Highway 1 Bridge. The foundation under a local business has
18 dropped 2.2 feet as a result of the increased tidal scour, requiring emergency piling
19 repair. Studies conducted by Philip Williams and Associates (1992) and Malzone and
20 Kvitek (1994) have shown that tidal volume in the slough has increased over time, and
21 since the tidal prism (volume of water exchanged over an average tidal cycle) has not
22 reached an equilibrium, increased current speeds and tidal scour can be expected.

23 *Seismicity and Faulting*

24 Monterey Bay is located within the active San Andreas Fault System, a transform plate
25 margin between the Pacific and North American tectonic plates. The historic slip rate of
26 the fault across the central part of its active trace is 0.14 inches (35 mm) per year, but
27 the slip rate between the North American and Pacific Plates is 0.22 inches (55 mm) per
28 year. The 0.08 inch (20 mm) per year discrepancy is believed to be accommodated by
29 other active fault systems within the San Andreas Fault System, i.e., the Monterey Bay
30 Fault Zone and the Palo Colorado-San Gregorio Fault System (Greene 1973; Fugro
31 2004; Cockerham et al. 1990; Weber et al. 1980).

32 Estimates of slip rates along the San Gregorio Fault range between 0.01 and 0.02
33 inches per year (3 and 5 mm) (The Working Group on Northern California Earthquake
34 Potential 1996). An absence of seismicity for the southern part of the San Gregorio
35 Fault has been documented in MOISE data, indicating that the southern portion of the

1 fault is locked and potentially accumulating strain that could be released in a large
2 earthquake. Alternatively, this strain may be accumulating in the nearby Monterey Bay
3 Fault Zone (Begnaud et al. 2000; Begnaud and Stakes 2000).

4 The California Division of Mines and Geology has listed the San Gregorio Fault as
5 having the potential for a significant magnitude quake (Mw of 6.0 or greater). The
6 USGS estimates a 25 percent probability of an earthquake with a Mw of 6.7 or greater
7 occurring in the area between the San Andreas and San Gregorio faults in the next 30
8 years (The Working Group on Northern California Earthquake Potential 1999). In
9 addition, the USGS report estimates an average probability for an earthquake occurring
10 along the San Andreas Fault at 10 percent, with slightly higher probabilities (8 percent)
11 on the northern strands than on the southern strands (6 percent).

12 The Loma Prieta Earthquake is the most significant and damaging earthquake in recent
13 history in the Monterey Bay region. The magnitude Mw 6.9 quake occurred on October
14 17, 1989. The epicenter was located approximately 10 miles (16 km) west of the city of
15 Santa Cruz, in the Santa Cruz Mountains, at Loma Prieta. As much as 6 feet (2 m) of
16 slip was recorded along the San Andreas Fault System. Downtown Santa Cruz was
17 particularly impacted due to the proximity of the epicenter, and damage in the San
18 Francisco Bay Area was widespread. The earthquake caused a small tsunami which
19 was recorded at several locations throughout Monterey Bay. In Moss Landing,
20 liquefaction occurred in underlying sediments, causing sediment to differentially settle
21 and the ground to crack, ultimately resulting in extensive damage to roadways and
22 buildings (Greene et al. 1991b). Moss Landing Marine Lab was forced to close many of
23 its facilities.

24 *Turbidity Currents*

25 Turbidity currents are powerful, short-lived, gravity-driven currents, consisting of a
26 mixture of sediments and seawater of a greater density than that of the surrounding
27 water. These currents are triggered in a variety of ways, including tsunamis, large
28 storm waves, earthquakes, tectonic movement, over supply of sediment causing
29 instability, and from the discharge sediment-laden rivers. Turbidity currents flow at or
30 near the seafloor and are often composed of sediment ranging from fine-silts and clay to
31 large boulders and can travel at speeds greater than 55 miles per hour (90 km per
32 hour), carrying 3 kilograms per cubic meter of material and spreading it over a distance
33 of 1,000 km from the source (Kennett 1982). These currents typically flow down
34 submarine canyons and then across submarine fans located at the base of the canyons.

1 Important evidence for the speed and force of turbidity currents is based on data
2 gathered from the breaking of a series of submarine cables. The most famous example
3 is a turbidity current which resulted from an earthquake on the Grand Banks,
4 Newfoundland, in 1929. This turbidity current snapped a series of cables as it
5 progressed downslope over a 13-hour period. The cables in that example were
6 positioned parallel to bathymetry contours (Kennett 1982; Brown et al. 1989).

7 Turbidity currents are a potential hazard wherever steep slopes are combined with
8 loose sediments. Monterey Bay is a seismically active area, increasing the possibility of
9 turbidity currents. Turbidity currents have been documented in Monterey Bay due to
10 sediment overloading at the head of Monterey Canyon and mass wasting along the
11 canyon walls (Greene et al. 1991b; Greene 1990; Greene et al. 2002; Fugro 2004).

12 *Tsunamis*

13 Tsunamis are triggered in a body of water by a sudden movement, such as a large-
14 scale slump or slide, which is often caused by earthquakes, movement of the oceans
15 crust, or large explosions. Tsunamis have extremely long wave periods and wave
16 lengths and can travel at great speeds. The potential of a tsunami to cause great
17 damage to coastal communities depends on coastline orientation, coastline shape, and
18 local bathymetry (Ingmanson and Wallace 1995; Fugro 2004).

19 Many tsunamis have been recorded in the Monterey Bay area since 1896 (Fugro 2004).
20 The most recent tsunami was generated by the Loma Prieta Earthquake of 1989. The
21 largest vertical shoreline run-up was recorded at 3.3 feet (1 m) at Moss Landing, in the
22 center of Monterey Bay. Eyewitnesses at Moss Landing described a sudden withdrawal
23 of water from the Moss Landing Harbor, followed a couple minutes later by a flood of
24 incoming water which was linked to either a single or a combination of slumps, slides,
25 and liquefaction (Greene 1991).

26 Tsunami waves themselves do not pose a significant threat to submarine cables, but
27 the events that generate tsunamis (landslides, earthquakes, volcanic eruptions) may
28 pose hazards to a cable. In addition, a resulting tsunami may damage or destroy
29 coastal infrastructure, thereby affecting cable operations (Fugro 2004).

30 *Volcanic Activity*

31 There is no active volcanism in the Monterey Bay area.

Sea Route Geology

Methodology

A comprehensive data set including interpretations of side-scan sonar imagery and seismic profiles, detailed bathymetry (provided by MBARI), mini-cone penetrometer test results, and standard cone penetrometer results (from a 1999 survey performed for MCI) were reviewed for the entire length of the MARS cable route. For detailed survey methods, descriptions of the equipment used for the surveys, and detailed burial assessment results, see the Geophysical and Burial Assessment Survey Results by Fugro (2004), on file with the California State Lands Commission.

Additional data provided by MBARI included digital side-scan sonar image mosaics, sub-bottom profile imagery, and digital images of the seafloor, provided by a remotely operated vehicle (ROV). These data were reviewed, analyzed, and compared to scientific literature available for the Monterey Bay region, in the form of peer-reviewed publications, geologic and structural maps, and digital GIS files. A generalized description of the geology along the cable route is discussed below and documented in Figures 4.4-6, 4.4-7 and 4.4-8, and Table 4.4-1. Descriptions of cable types are discussed in Table 4.4-2. In addition, a more detailed Project route description from Fugro (2004) is included as Appendix F.

Table 4.4-1. Summary of Cable Route Subsurface Conditions (after Fugro 2004)

Cable Location (Miles) (Km)	Percent Burial	Water Depth (Feet) (Meters)	Expected Burial Depth	Slope/ Degree	Cable Type	Soil Type	Comments
0 to 18.6 0.0 to ± 30	59.2	55 to 288 17 to 88	Full	< 5	SAL	Loose to medium dense sand or very soft to soft clay	Occurrences of dense/coarse sand.
± 18.6 to 19.7 ± 30 to 31.7	3.3	288 to 300 88 to 92	Partial	< 5	LWP	Very soft clay over very dense sand	Locally no burial may be achieved because of rock outcrops.
19.7 to 25.2 31.7 to 40.6	17.5	300 to 1448 92 to 441	Limited / No burial	6-11	SPA	Very stiff to hard clay/rock	Extensive rock outcrops. San Gregorio Fault deformation zone. Some burial may be achieved up to 0.9 yards. Most difficult terrain of Project route.

Cable Location (Miles) (Km)	Percent Burial	Water Depth (Feet) (Meters)	Expected Burial Depth	Slope/Degree	Cable Type	Soil Type	Comments
25.2 to ± 26.1 40.6 to ± 42	2.7	1448 to 1556 441 to 475	Partial	6 to 8	LWP	Soft to very stiff clay, weakly cemented	Locally no burial may be achieved because of rock outcrops.
± 26.1 to 31.7 ± 42 to 51	17.6	1556 to 2923 475 to 891	Full	8 to <5	LWP	Very soft to firm clay	Risk of plow sinkage.

Table 4.4-2. Descriptions of Cables (after Fugro 2004)

Cable Type	Description
Single Armor Light (SAL)	Used to a maximum depth of 1,500 meters, when armor is required, and in areas where good burial is predicted. Typically used on medium depth continental shelves, on rocky terrain, and in areas where trawling is a risk.
Special Application (SPA)	Used to a maximum design depth of 6,000 to 7,000 meters, when surface-laid on continental slopes and in deep-sea areas where extra abrasion protection might be needed. Typical installation is 1,000 to 4,500 meters, where rocky terrain may occur.
Light Weight Protected (LWP)	Same application as for SPA cable but in more benign environments. Typical installation is from 1,500 to 8,000+ meters.

Subsurface Conditions

The initial 18.6 miles (30 km) of the Project route traverse the continental shelf, in water depths ranging from 55 to 288 feet (17 to ~88 m). The continental shelf is generally flat to gently sloping or rolling, and covered by a thick wedge of mostly soft, unconsolidated sand (Figures 4.4-6, 4.4-7, and 4.4-8, Image A), silt, and mud (Figure 4.4-8, Image B). This section of the cable route is characterized by sedimentary deposition. Currents in this location are generally not strong enough to erode bottom sediments. Side-scan sonar images revealed several sonar targets (possible obstructions) near the beginning of the Project route, in approximately 55 feet (17 m) of water. However, these possible obstructions are far enough from the route to not have an effect on the Project. The Monterey Bay Fault Zone traverses the cable alignment on the lower, i.e., seaward, portion of this area of thick, soft sediments.

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- 2 color takes two pages

1 page 2 for Figure 4.4-8

For the next 1.1 miles (1.7 km or 3.3 percent) of the Project route, between the water depths of roughly 288 to 300 feet (88 to 92 m), only partial or intermittent burial of the cable is expected (Figure 4.4-6). As the route turns southwest, the seafloor slope gradually increases towards the shelf break, but is still less than 5 degrees. Sub-bottom profile images reveal gently seaward dipping strata just below the seafloor surface and intermittent exposures on the seafloor surface. The intermittent outcrops are probably the Purisima Formation sandstone and siltstone. There is no evidence of strong erosive currents in this area.

The next 5.6 miles (9 km or 17.5 percent) of the Project route, between water depths of 300 to 1,450 feet (92 to 441 m), represent the most difficult terrain for cable burial and a variety of geohazards. Burial to the target depth of 3.3 feet (1 m) is not expected and most likely the cable will be exposed on the seafloor and possibly suspended over hard cemented clay, angular carbonate, and/or sandstone outcrops (Figures 4.4-7 and 4.4-8, Images C, D, and E). The slope increases considerably to over 10 degrees between water depths of 720 to 1,020 feet (200 to 310 m), as the Project route approaches the narrow neck of Smooth Ridge (Figure 4.4-7). This area is highly disturbed and contains a high concentration of both carbonate and sandstone outcrops. This deformation zone is probably the result of the San Gregorio Fault, interpreted in sub-bottom profiles, which would cross the cable route at a water depth of approximately 726 feet (227 m). Following the deformation zone, the seafloor slope gradually decreases as the route progresses further to the south; however hard carbonate outcrops and rubble exist in this area (Figure 4.4-8, Image F).

For the next 0.9 mile (1.4 km or 2.7 percent), down the lower neck of Smooth Ridge and onto the Smooth Ridge slope, between water depths of 1,448 through 1,556 feet (441 through 475 m), the concentration of exposed rock outcrop decreases as well as the seafloor slope. Stiff clay has been mapped throughout most of this area (Figure 4.4-7); however, fine sand and mud sediments thicken with depth.

The final 5.4 miles (9 km) of the Project route down Smooth Ridge slope, between the water depths of 1,556 through 2,923 feet (475 through 891 m), sediments consist of very soft to firm clay (Figure 4.4-7 and 4.4-8, Image G), which increase in thickness with water depth. The seafloor slope becomes less than 5 degrees (Figure 4.4-6). Table 4.4-1 on page 4.4-18 contains a summary of cable burial, water depth, and relevant subsurface conditions identified along the Project's cable route.

Geology of the Landing Areas

Moss Landing Harbor was created in 1947 when the U.S. Army Corps of Engineers (USACE) first dredged the Old Salinas River channel at the mouth of Elkhorn Slough. Permanent jetties placed along the north and south sides of the Harbor entrance provide year-round access between the Pacific Ocean and Elkhorn Slough. The Harbor entrance and Elkhorn Slough main channel divides Moss Landing into two parts, the North and South Harbor (Figure 4.4-3). The North Harbor area occupies a portion of the Old Salinas River near its confluence with Bennett Slough, and the South Harbor area occupies portions of both the Old Salinas River and the mouth of Moro Cojo Slough.

Surficial geology in the harbor area consists of sands, silts, and clays with interbedded gravels deposited in marine/estuarine, fluvial, and dune environments (Rutherford and Chekene 1992, 1999). Harbor dredging indicates that bottom sediments are generally composed of sand around the entrance channel and grade to silt and clay in the northern and southern ends of the Harbor. Sediment accumulation in the Harbor and sand spit areas relies on four sediment sources: littoral drift, watershed runoff, wind-transported sediment, and shoreline erosion inside the Harbor.

Nearshore seismic reflection profiles and onshore well hole data interpreted by Greene (1977), as well as geotechnical reports (Rutherford and Chekene 1992 and 1999), indicate that unconsolidated Quaternary sand dune deposits with some silt and clay layers (associated with the Old Salinas River and Elkhorn Slough) are deposited at least 990 feet (300 m) thick over well consolidated Purisima sandstone in the Harbor area.

East of the Harbor, mud flats and tidal marshes of the Elkhorn Slough watershed extend inland for nearly 7 miles (11 km). The 4,000-acre Elkhorn Slough watershed is linked with the Pacific Ocean and flushed by the diurnal tides that flow through the Harbor. Immediately east of Highway 1 and north of the main Elkhorn Slough channel is Moss Landing Wildlife Area, which has recently been restored to tidal action and is managed by the California Department of Fish and Game. Upland areas immediately surrounding the Harbor consist of low rolling hills.

4.4.2 Regulatory Setting

State

The Alquist-Priolo Special Studies Zones Act of 1972

The criteria most commonly used to estimate fault activity in California are described in this act, which addresses only surface fault-rupture hazards. The legislative guidelines to determine fault activity status are based on the age of the youngest geologic unit offset by the fault. An active fault is described by the California Division of Mines and Geology (CDMG) as a fault that has “had surface displacement within Holocene time (about the last 11,000 years).” A potentially active fault is defined as “any fault that showed evidence of surface displacement during Quaternary time (last 1.6 million years).” However, offshore faults, such as those located in Monterey Bay, are not classified under this act. Therefore, this act does not apply to this project.

The Seismic Hazards Mapping Act

These regulations were promulgated for the purpose of protecting public safety from the effects of strong ground shaking, liquefaction, landslides, other ground failures, or other hazards caused by earthquakes. Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (CDMG 1997), constitutes the guidelines for evaluating seismic hazards other than surface fault-rupture, and for recommending mitigation measures as required by PRC Section 2695(a). However, to date the California Geological Survey (CGS) has not zoned offshore California under the Seismic Hazard Mapping Act. Therefore, this act does not apply to this project.

4.4.3 Significance Criteria

A geological impact is considered significant if:

- The Project causes any change to unique geological features, such as exposed hard substrate;
- The Project triggers or accelerates any geological processes, such as terrestrial or marine landslides;
- The Project increases the probability of additional environmental damage or impacts if earthquake-induced ground motion, coastal erosion, or submarine erosion damages Project components that must summarily be replaced;
- The Project causes any alteration of topography that is not restored to its natural conditions within 6 months of the Project’s completion;

- Project installation prevents the recovery of economic minerals; or
- The Project exposes people to increased risk of harm from seismic events.

4.4.4 Impact Analysis and Mitigation

The Project is expected to have a less than significant impact, or no impact, on the environmental issues identified below.

The Project installation activities would not change any unique geological features, such as exposed hard substrate.

HDD would place the conduit and cable under the beach such that it would not affect nearshore or onshore topography or slope stability.

Marine landslides and slumping triggered by cable installation would be unlikely because: (1) trenching will not occur on slopes steeper than 8 degrees, and (2) the cable will be placed as perpendicular as possible to slopes (such as rocky, non-burial areas).

Cable repairs that may be required as a consequence of damage from earthquake-induced ground motion would not cause no more alteration of bottom topography or trigger submarine slope failures than installation activities, in both nearshore and offshore areas.

Subsea cable installation would not result in substantial alteration of topography.

Poorly consolidated nearshore sediments could result in HDD frac-outs; however, as discussed in Section 4.6, no significant long-term impacts on water or sediment quality would occur.

Potential exposure and/or damage of the nearshore conduit and cable, by either tidal scour or landward transgression of Monterey Canyon, would not adversely affect the geologic environment. Similarly, exposure of the cable along the sea route subsequent to burial would not adversely affect the geologic environment.

Project installation would not prevent the recovery of economic minerals, as oil and gas exploration is prohibited within the MBNMS.

The Project could result in very limited exposure of additional people to increased risk of harm from seismic events.

Cable removal would result in similar or less impacts than those described for cable installation.

Sea Route

Impact GEO-1: Submarine Slope Failures

Marine landslides and slumping triggered by cable installation would be unlikely because: (1) trenching would not occur on slopes steeper than 8 degrees, and (2) the cable will be placed as perpendicular as possible to slopes (such as rocky, non-burial areas). (Class III)

During cable installation, the cable would be buried by means of a plow to a depth of up to 3.3 feet (1 m) in all soft sediment areas. The Fugro Geophysical and Burial Assessment Survey, including geo-referenced side-scan sonar images, were evaluated and compared with independently collected geophysical data and published maps in GIS. The proposed MARS cable route was plotted with both sets of data, and measurements were made to confirm Fugro's estimate that approximately 76 percent of the cable would be fully buried, 6 percent would be partially buried at depths less than 3.3 feet (1 m), and the remaining 18 percent would be laid on the seafloor over areas of rock outcrops and/or boulders.

On average, use of a plow along portions of the route for cable installation would cause approximately a 6-foot (2-m) wide area of bottom disturbance, which includes the trench and sidecast berms on both sides of the burial trench. The plow is supported on the seafloor by skids (skis), which prevent significant disturbance of the seafloor and the settlement of the plow frame into the seafloor during the cable burial process. The plow blade would penetrate the seafloor to a depth of just over 3 feet (0.9 m), displacing the sediment just ahead of the plow to create a trench about 3 inches (7.6 cm) wide. The 1.1-inch (28-mm diameter) fiber optic cable would be forced into the trench just behind the plow blade as the plow advances (pulled by the cable laying vessel). Bottom materials (clays, sands, or muds) displaced by the plow blade would then be returned to the trench by an attachment mounted on the plow frame and just behind the cable, thus filling the trench and minimizing bottom disturbance.

Surficial slumping is not anticipated as a result of trenching in soft sediments because the plow would be: (1) pulled at a slow rate of 0.5 to 1.0 knot (as opposed to using thrusters such as on a remotely operated vehicle [ROV], which can cause bottom disturbances); (2) create only a 3-inch wide trench; (3) primarily trenching straight up and down slopes (as opposed to traversing, which causes undercutting); and (4) would

1 be trenching on slopes of 8 degrees or less. Soft-sediment slumping on marine slopes
2 is primarily caused by seismically-induced ground shaking, which would create potential
3 conditions for slope failure orders of magnitude greater than that created by trenching
4 with a plow (personal communication, Gary Green 2000). Similarly, rockslides or
5 landslides during cable installation would be unlikely in areas where cable burial is not
6 possible, as the maximum slope gradient is only 11 degrees, the cable would primarily
7 be laid perpendicular to these slopes, i.e., straight up and down, and bottom
8 disturbance would be minimal. Therefore, the potential for cable installation to trigger
9 slope failure would be less than significant (Class III).

10 **Impact GEO-2: Earthquake-Induced Cable Damage**

11 **Cable repairs that may be required as a consequence of earthquake-induced**
12 **ground motion damages would result in no more alteration of bottom topography**
13 **or trigger submarine slope failures than installation activities. (Class III)**

14 The Project cable would traverse the active Monterey Bay and Palo Coronado-San
15 Gregorio fault zones. Quaternary sediments overlying the Monterey Bay Fault Zone
16 display no evidence of vertical earthquake-induced fault movement; however, small to
17 moderate earthquakes attributed to this fault indicated strike-slip, i.e., lateral, movement
18 is occurring along the fault. The most active portion of the Palo Coronado-San Gregorio
19 Fault Zone is the San Gregorio Fault, which displays both strike-slip and thrust, i.e.,
20 vertical, movement. Movement along either of these fault zones during a large
21 earthquake could potentially damage or sever the submarine cable. However, because
22 offshore faulting at the proposed depth of the cable (upper few feet) would likely occur
23 in soft sediments, the medium through which fault movement would occur would be
24 relatively cohesionless, i.e., flexible, compared to onshore geologic materials.
25 Therefore, the potential for cable rupture would be diminished.

26 Similarly, with respect to seismically-induced shaking, the primary interaction between
27 the radiated seismic wave field and the marine cable is not regarded as much of a
28 threat to the cable, largely due to the compliance of the soft sediment surrounding a
29 buried submarine cable. Rather, the cause for concern is a potential secondary effect in
30 which the passage of the seismic wave may trigger a slumping event (see Impact **GEO-**
31 **1**). Vertical accelerations in excess of about 30 percent g are thought to be of concern
32 to submarine cables, especially over unconsolidated sediments with slopes greater than
33 about 10 to 20 degrees. Cable installation would not occur in soft sediments on slopes
34 in excess of 8 degrees, thereby reducing the likelihood of slope failure. Slopes in
35 excess of 8 degrees along the alignment, such as on the neck of the Smooth Ridge, are
36 underlain by rock where soft-sediment slumping would likely not occur. In localized

1 areas where the slopes are up to 11 degrees and vertical accelerations may be in
2 excess of 30 percent g, the cable would traverse slopes generally perpendicular to the
3 slope gradient, i.e., straight up and down. Slope failure would occur parallel to the
4 direction of the cable alignment, thus significantly reducing the potential for cable
5 damage.

6 In the event that the cable was to break, it would not adversely affect the environment.
7 However, impacts would occur due to temporary disturbance of the seafloor during
8 cable repairs. Geologic impacts associated with cable repair would be similar to those
9 associated with cable installation. In addition, similar to that described above for the
10 impact of Submarine Slope Failures, cable repairs in soft sediment areas would not
11 likely result in slope instability due to the gentle slope gradient and limited bottom
12 disturbance. Therefore, impacts would be less than significant (Class III).

13 **Impact GEO-3: Alteration of Topography**

14 **Subsea cable installation would not result in substantial alteration of topography.** 15 **(Class III)**

16 Substantial alteration of the existing bottom topography would not occur as a result of
17 cable installation or repair. As discussed for the **Impact GEO-1** above, a 6-feet (2-m)
18 wide area of bottom disturbance would occur along the route as a result of cable
19 installation with the plow. In areas of complete cable burial, most of the bottom
20 materials displaced by the plow blade would be returned to the trench by an attachment
21 mounted on the plow frame and just behind the cable, thus minimizing the potential for
22 creation of sidecast berms during trenching. However, only partial burial is anticipated
23 along 6 percent of the route (3.1 of 51 km) (Figure 4.4-6), in very low to no-relief hard-
24 bottom areas where the substrate is comprised of clay over dense sand or weakly
25 cemented material. Plowing in these areas could result in the creation of sidecast
26 berms that may range from several inches to 1 meter in height on both sides of the
27 burial trench. This potential outcome is based on results from the Global West cable
28 project off California that achieved partial burial in similar low to no-relief hard substrate,
29 but created sidecast berms (personal observation, Heilprin and Lissner 2000). Bottom
30 currents and submarine depositional processes would partially erode these berms over
31 time, but the topography would not be restored to original conditions within 6 month's of
32 the Project's completion. However, several inches to 1 meter of bottom relief is not
33 considered substantial alteration of topography. Therefore, impacts would be less than
34 significant (Class III).

1 **Landing Areas**

2 **Impact GEO-4: HDD Frac-Outs**

3 **Poorly consolidated nearshore sediments could result in HDD frac-outs and**
4 **tidal/wave action scour. (Class III)**

5 As part of the Project, HDD would be completed in weakly consolidated to
6 unconsolidated, relatively coarse-grained sediments. The major concern associated
7 with the HDD method of construction is frac-outs, which are generally defined as an
8 inadvertent return of drilling fluids to the ground surface. Frac-outs could potentially
9 result in adverse impacts on marine water quality. Frac-outs generally occur in coarse
10 grained, unconsolidated sediments, such as typically occurs in the nearshore
11 environment, or in fractured bedrock. HDD in consolidated clay, silt, and sand generally
12 does not result in frac-outs, as these types of sediments allow a cohesive mudpack, or
13 filter-pack, to form on the walls of the borehole. The integrity of the mudpack in these
14 types of sediments prevents the drilling mud from permeating the surrounding strata
15 and migrating to the ground surface or groundwater. The potential for frac-outs also
16 increases with increasing length of the HDD borehole. Longer drilling reaches require
17 increased hydraulic head for effective drilling at increased distances from the drill rig.
18 This increased hydraulic head increases the pressure on the surrounding strata, thus
19 increasing the potential for frac-outs.

20 Shallow seismic reflection data indicate that nearshore sediments, to the depth of the
21 proposed HDD borehole, consist of weakly consolidated sands and unconsolidated
22 sands and gravels, which could be prone to frac-outs. However, as discussed in more
23 detail in Section 4.6, no significant long-term impacts on water or sediment quality
24 would occur (Class III).

25 **Impact GEO-5: Cable Scour and Submarine Canyon Headward Erosion**

26 **Poorly consolidated nearshore sediments could result in tidal/wave action scour**
27 **and exposure of the cable conduit. Similarly, headward erosion of the Monterey**
28 **Canyon could result in exposure of the cable conduit. (Class III)**

29 Tidal currents in and out of the Elkhorn Slough have increased dramatically since the
30 construction of the Moss Landing Harbor, causing extensive erosion in the Harbor
31 channel, adjacent banks, and throughout Elkhorn Slough to the east. As tidal volume
32 continues to increase, current velocities will increase to meet the tides. Increasing
33 currents will continue to erode the poorly consolidated sediments found in the Harbor

1 and the Slough. As a result, the nearshore cable conduit may become exposed over
2 the 25-year life span of the Project, resulting in potential conduit and cable damage.

3 In addition, the head of the Monterey Canyon lies just 100 to 300 feet offshore of Moss
4 Landing Harbor (Greene 1990). Sand eroded from beaches and mixed sediment
5 delivered to the coast by rivers is transported towards the Canyon head, which
6 comprises the uppermost depositional and erosional feature in the Monterey Canyon
7 System. Due to the relatively high frequency of geologic/seismic activity in this area, it
8 is possible over the 25-year life span of the Project that the Canyon head could
9 transgress shoreward towards the Harbor as a result of seismically induced slumping
10 (Best & Griggs 1991; Greene et al. 2002; Wolf 1970; Mitts 2003). If such an event were
11 to occur, the nearshore cable conduit may become exposed, resulting in potential
12 conduit and cable damage.

13 However, in the event that the conduit and/or cable were to break or become severely
14 damaged, it would not adversely affect the geologic environment. The conduit and
15 enclosed cable would be abandoned, by pulling the conduit towards the landing, and re-
16 installed at a greater depth using HDD. Aside from potential marine water quality
17 impacts due to erosion of stockpiled materials and potential frac-outs of drilling fluids
18 (see Section 4.6), this drilling method would have no impact on topography or slope
19 stability, as the conduit would be placed at depth under the beach and nearshore
20 deposits. Therefore, impacts due to potential conduit or cable damage in the landing
21 area would be less than significant (Class III).

22 **Impact GEO-6: Earthquake-Induced Cable Damage**

23 **Conduit or cable repairs that may be required as a consequence of earthquake-**
24 **induced ground motion damages would result in no more alteration of bottom**
25 **topography or trigger slope failures than installation activities. (Class III)**

26 As noted above, during the 1989 Loma Prieta Earthquake, liquefaction occurred at
27 Moss Landing in underlying sediments, causing sediment to differentially settle and the
28 ground to crack, ultimately resulting in extensive damage to roadways and buildings
29 (Greene et al. 1991b), and Moss Landing Marine Laboratory was forced to close many
30 of its facilities. Another major earthquake could impact the proposed shore landing
31 locations in a similar manner. Liquefaction and differential settlement associated with a
32 new earthquake could result in conduit and/or cable damage near the landing.
33 However, in the event that the cable broke, it would not adversely affect the geologic
34 environment. HDD would be used to repair the conduit or cable. Aside from potential
35 marine water quality impacts due to erosion of stockpiled materials and potential frac-

outs of drilling fluids (see Section 4.6), this drilling method would have no impact on topography or slope stability, as the conduit would be placed under the beach and nearshore deposits. Therefore, impacts due to potential conduit or cable damage in the landing area would be less than significant (Class III).

Impact GEO-7: Increased Seismic Exposure to Personnel

The Project could result in very limited exposure of additional people to increased risk of harm from seismic events. (Class III)

Development anywhere along the California coastline implies a certain amount of risk. The California coast is seismically active and subject to hazards caused by earthquakes, such as liquefaction and tsunamis. These risks are multiplied by the fact that the Moss Landing Harbor lies at sea level on poorly consolidated sediment, thereby increasing the risk of tsunami-induced flooding and seismically-induced liquefaction.

Project operations may involve a slight increase in the number of personnel working at the MBARI facility at Moss Landing. These additional personnel would be subject to potential seismically-induced ground failure and tsunami-induced flooding. However, this seismic susceptibility is present throughout low-lying areas of coastal California and not unique to the project area. No new above ground structures, which might be susceptible to structural failure during an earthquake, would be built as part of the Project. Therefore, the increased risk of harm during seismic events would be less than significant (Class III).

Sea Route and Landing Areas

Impact GEO-8: Cable Removal

Cable removal would result in similar or less impacts than those described for cable installation. (Class III)

Cable removal in the nearshore area would involve pulling the cable from within the conduit, toward the landing area. HDD would not be required; therefore, potential frac-outs of bentonite-based drilling mud would not occur. In addition, no other geologic impacts would occur during cable removal in the nearshore area.

Cable removal seaward of the HDD conduit would involve water jet excavation and cable severing activities. For reasons similar to those described in **Impact GEO-1** in association with cable installation, the potential for cable removal to trigger slope failures would be less than significant. Jet excavation would displace sediments

overlying the cable. However, in contrast to cable installation, in which excavated sediments would be returned to the trench by the plow in areas of anticipated complete burial and in which sidecast berms would be created in areas of partial burial, water jet excavation would disperse the sediments across the seafloor adjacent to the trench and, with the exception of sloughed sediments, leave a partially open trench. Such dispersal of sediments and partially open trench conditions would result in minimal changes in topography. Bottom currents and associated depositional processes would minimize these minor changes in topography over time. The rate at which this occurred would depend on localized submarine erosion and deposition rates along the cable alignment. Therefore, geologic impacts associated with cable removal would be less than significant.

Table 4.4-3. Summary of Geology and Soils Impacts and Mitigation Measures

Impact	Mitigation Measures
GEO-1: Potential for marine landslides and slumping triggered by cable installation. (Class III)	None required.
GEO-2: Cable repairs along the sea route would result in no more alteration of bottom topography or trigger submarine slope failures than installation activities. (Class III)	None required.
GEO-3: Subsea cable installation would not result in substantial alteration of topography. (Class III)	None required.
GEO-4: Poorly consolidated nearshore sediments could result in HDD frac-outs. (Class III)	None required.
GEO-5: Potential exposure and/or damage of the nearshore conduit and cable, by either tidal scour or landward transgression of Monterey Canyon, would not adversely affect the geologic environment. (Class III)	None required.
GEO-6: Conduit or cable repairs at the landing area would result in no more alteration of bottom topography or trigger slope failures than installation activities. (Class III)	None required.
GEO-7: The Project could result in very limited exposure of additional people to increased risk of harm from seismic events. (Class III)	None required.
GEO-8: Cable removal would result in similar or less impacts than those described for cable installation. (Class III)	None required.

4.4.5 Cumulative Impacts

Sea Route

The nature and scale of the proposed Project are such that there would be no significant effects on the geology or geologic processes that occur along the sea route. Potential geologic impacts would be localized and limited to the seafloor along the buried portion of the cable route. In these areas, a narrow strip of seafloor (Section 2.2) would be displaced and then predominantly replaced during the cable burial phase of the Project. Localized sidecast berms may be created, resulting in minor changes in topography. Secondary effects could include possible localized soft-sediment slump (or shallow landslide) inducement. However, such slope failures are unlikely due to the gentle, i.e., 8 degrees or less, slope gradient in areas of cable burial. Therefore, such impacts associated with the proposed Project are not expected to be significant, as explained in Section 4.4.4. None of the identified cumulative projects would result in potential marine slope instability or changes in marine topography in nearshore areas or on the continental slope of Monterey Bay. Therefore, cumulatively considerable impacts would not occur and cumulative impacts are less than significant (Class III).

Landing Areas

Portions of the cable route in conduit and above-ground on utility poles would not impact the geology, soils, or topography, therefore, no cumulative impacts are anticipated. See Section 4.6 for potential cumulative water quality impacts due to frac-outs and erosion. The MARS project and related cumulative projects would result in a small incremental increase in the amount of persons and property exposed to earthquake-related hazards. Similarly, cumulative projects would result in a small incremental increase in the amount of persons and property exposed to earthquake-related hazards. However, each project would be completed utilizing standard earthquake resistant design, as appropriate, in accordance with local and state regulations, including but not limited to provisions of the Uniform Building Code. Therefore, potential cumulative seismic impacts would be reduced to less than significant levels.

4.4.6 Alternative Landings

Alternative Landing Area 1: Duke Energy Pipeline to MBARI Property

Alternative Landing Area 1 would utilize an existing pipeline owned by Duke Energy to bring the cable to shore on the north side of the Moss Landing Harbor entrance (Figure 4.4-3). From this point near Jetty Road, HDD would be used to install a 5-inch diameter pipe, housing the MARS cable, below the Harbor entrance channel to the same shore

1 landing location as the proposed Project. Impacts associated with the sea route would
2 be similar to the proposed Project (Class III).

3 Impacts in the landing area would be greater than under the proposed Project, but still
4 less than significant (Class III). The southeast portion of the sand spit, located north of
5 the Harbor, has experienced wave- and wind-derived erosion over time. Although this
6 southeastern shoreline is generally considered an area of wind-driven sediment
7 deposition, the effects of increased tidal currents, caused by increasing tidal volume
8 over time, may cause erosive scour in this location. In addition, wind-related erosion
9 has caused a part of the parking area approximately 320 feet north of the cable landing
10 site to require repair. Such tidal and wind-related erosion could potentially expose
11 portions of the cable during the 25-year life span of the Project.

12 **Alternative Landing Area 2: Moss Landing Marine Laboratories (MLML) Pier**

13 This alternative differs from the Project and Alternative Landing Area 1 by proposing to
14 bring the MARS cable to shore at the proposed new MLML research pier, which has not
15 been constructed. The proposed pier would be approximately 0.6 mile (1 km) south of
16 the Harbor channel. From the pier, the cable would be placed in a conduit and would
17 follow the same path as an existing intake pipe that supplies sea water to the
18 Applicant's shore facilities (see Figure 4.4-3).

19 Geologic impacts are greater under this alternative than for the proposed Project, as the
20 initial offshore cable segment would be placed across the head of the active Monterey
21 Canyon. This portion of the canyon is characterized by steep slopes and erosive
22 turbidity currents, which are potential hazards to the integrity of cable projects. Turbidity
23 currents have been documented in Monterey Bay due to sediment overloading at the
24 head of Monterey Canyon and mass wasting along the canyon walls (Greene et al.
25 1991b; Greene 1990; Greene et al. 2002; Fugro 2004). Monterey Bay is a seismically
26 active region, which increases the possibility of seismically-induced turbidity currents.
27 The head of Monterey Canyon may be the most active part of the canyon in terms of
28 sediment transport. As much as 523,000 yd³ (400,000 m³) of sand per year is actively
29 transported down the heads of Monterey Canyon. Turbidity currents have been
30 observed in the head of Monterey Canyon immediately following the Loma Prieta
31 earthquake, high-energy storm events, and possibly from sediment overloading (Greene
32 et al. 1991b; Greene 1990; Greene et al. 2002). In addition, MBARI and the USGS
33 have lost oceanographic instrumentation in this area due to sediment transport activity
34 in the canyon heads.

1 To date, there is no method to predict seismic events, slides, or turbidity currents;
2 therefore, the most effective way to minimize the damage of a potential turbidity current
3 (or other slope failure) is to lay the cable in the same orientation as the slope gradient,
4 in order to minimize the area the cable is exposed, and to appropriately armor the cable
5 in areas where this threat is most likely to occur. Under this alternative, the Project
6 cable would be laid perpendicular to the Monterey Canyon axis, increasing the risk that
7 the cable could be damaged or ruptured by a turbidity current. Cable damage or
8 rupture would necessitate cable repairs, which would result in additional bottom
9 disturbance and possible triggering of additional turbidity currents. However, as
10 described for the proposed Project, geologic impacts associated with this alternative
11 would be less than significant (Class III).

12 **No Project/Action Alternative**

13 Under this alternative, the cable would not be installed, resulting in no onshore or
14 offshore geologic impacts.